GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. ______

Project No. A-3205

DATE 4/13/82

Project Director: C.H. Cash

~~School~~/Lab RAIL/OOD

Sponsor: U.S. Army Missile Command; Redstone Arsenal, AL

Type Agreement: Del. Order No. 00046 under Contract DAAH01-81-D-A003

Award Period: From 3/24/82 To 9/30/82 (Performance) 10/30/82 (Reports)

Sponsor Amount: $50,000

Contracted through: ~~GTRI~~/GIT

Cost Sharing: None

Title: Helicopter Mast Mounted Sensor Analysis Refinement

ADMINISTRATIVE DATA

OCA Contact William F. Brown x4820

1) Sponsor Technical Contact:

~~John Hatcher/DRSMI-RkS~~
~~USAMICOM~~
~~Redstone Arsenal, AL 35898~~

Hallum

2) Sponsor Admin/Contractual Matters:

Thomas A. Bryant
206 O'Keefe Building
Office of Naval Research
Resident Representative

Defense Priority Rating: DO-A2

Security Classification: Unclassified

RESTRICTIONS

See Attached Gov't. Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Government - except that items costing less than $1,000 vests with GIT if prior approval to purchase is obtained from the Sponsor.

COMMENTS:

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FORM OCA 4:781

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

5R55-N21

Date 3/2/83

Project Title: Helicopter Mast Mounted Sensor Analysis Refinement

Project No: A-3205

Project Director: C. H. Cash

Sponsor: U.S. Army Missile Command; Redstone Arsenal, AL

Effective Termination Date: 9/30/82

Clearance of Accounting Charges: 10/30/82

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [x] Final Report of Inventions
- [x] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______________

Assigned to: RAIL/OOD (School/Laboratory)

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FORM OCA 10:781

A-3205

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

June 2, 1982

U.S. Army Missile Command
Advanced Sensors Directorate
Redstone Arsenal, Alabama 35809

Attention: Mr. John Hatcher
DRSMI-RES

Subject: Monthly Progress Letter and Cost Report for April and May 1982, Contract DAAH01-81-D-A003, Delivery Order No. 00046

Gentlemen:

During this reporting period activities were conducted in the following areas:

1. Initiated plans for refinement of the analysis conducted under subject contract delivery order 00028.
2. Conducted meetings and discussions with contractor and government personnel concerning the results of the Georgia Tech analysis and the availability of data to substantiate or modify the analysis.
3. Began investigations of alternate processing approaches that may affect the time line analysis.
4. Promulgated plans to support the government in a briefing to Ft. Rucker.

Cost Report

Project Duration	6 months
Months into Project	2 months
Funds Contracted	$50,000
Funds Expended	$11,345.47
Funds Remaining	$38,654.53

Respectfully submitted

[redacted]

Carlton H. Cash, Project Director

APPROVED: [redacted]

Jerry L. Eaves
Associate Director
Radar & Instrumentation Laboratory

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

July 9, 1982

U.S. Army Missile Command
Advanced Sensors Directorate
Redstone Arsenal, Alabama 35809

Attention: Mr. John Hatcher
DRSMI-RES

Subject: Monthly Progress Letter and Cost Report for June 1982, Contract DAAH01-81-D-A003, Delivery Order No. 00046

Gentlemen:

During this reporting period activities were conducted in the following areas:

1. Meetings and discussions were conducted at MICOM to discuss a proposed briefing to the user at Fort Rucker in July.

2. A set of viewgraphs to be used at the Ft. Rucker briefing in July have been prepared (Enclosure 1). It will be noted that the processing time line viewgraph predicts somewhat better performance than previously predicted for large numbers of high priority targets.

3. Improved signal processing algorithms have been analyzed to refine the time line analysis reported in the final technical report of February 1982.

   This analysis revealed that a less than optimum algorithm was used for the Case 2 signal processing. This subsequent Analysis shows that the use of a slightly different (but no more complex) algorithm will result in reduced processing times than previously reported for large numbers of high priority targets. Thirty selected high priority targets can be processed in 12 seconds, as shown in the processing time line viewgraph of Enclosure 1.

Cost Report

Project Duration	6 months
Months into Project	3 months
Funds Contracted	$50,000
Funds Expended	$18,801.51
Funds Remaining	$31,196.49

Respectfully submitted,

[redacted]

Carlton H. Cash
Project Director

saw

Enclosures

APPROVED: [redacted]

Jerry L. Eaves
Associate Director
Radar & Instrumentation
Laboratory

HELICOPTER MAST MOUNTED
SENSOR ANALYSIS

Georgia Institute of Technology
Engineering Experiment Station
Radar And Instrumentation Laboratory

TASK DESCRIPTION

DETERMINE MAST MOUNTED RFDF CAPABILITIES

- REVIEW EXISTING SYSTEMS
- THREAT EMITTERS
- SPURIOUS EMITTERS
- ANGLE ACCURACY EFFECTS
- MULTIPLE EMITTER EFFECTS

ANALYSIS APPROACH

- COLLECT AND ANALYZE CONTRACTOR SYSTEM CONFIGURATION DATA
- DEFINE GENERIC DF SYSTEM
- IDENTIFY PRIMARY ERROR SOURCES
- QUANTIFY ERROR MAGNITUDES
- FORMULATE TIMELINE EQUATION
- QUANTIFY PROCESSING EFFECTS ON TIMELINES

LIMITATIONS OF THE ANALYSIS

- Lack of Experimental Data
  - Multipath Effects
  - Rotor Blade Modulation Effects
- Radiation Environment Ill-Defined
  - Quantity of Threats
  - Threat Prioritization

CHARACTERISTICS OF EXISTING DF SYSTEM

- 360° RADAR WARNING
- IDENTIFICATION AND PRIORITIZATION OF EMITTERS
- ACCURATE DF IN FORWARD 90° SECTOR
- PROVIDES FIRE CONTROL DATA
- LIGHTWEIGHT (< 6 LBS. ABOVE ROTOR)*
- COMPACT (< 200 CU. IN. ABOVE ROTOR)*
- RUGGED
  - STANDARD RF COMPONENTS
  - DIGITAL PROCESSOR

* EXAMPLE DATA FOR PROPOSED T.I. SYSTEM

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY

RF INTERFEROMETER SIDELOBE DETECTION PERFORMANCE

EMITTER	TYPE	DETECTION RANGE (KM)
1	PULSE	30-33
2	PULSE	29-33
3	PULSE	7.1-8.9
4	PULSE	18-20
5	CW	2.7-3.0

GENERIC DF SYSTEM

- Uses Interferometer
- Superheterodyne Receiver
- Performs Initial Frequency Search
- Re-Examines Selected High-Priority Targets
- Reports Targets Out for Further Action

ERROR SOURCES

- THERMAL NOISE ERRORS
- AZIMUTH MULTIPATH ERRORS
- A/D QUANTIZATION ERRORS
- ROTOR BLADE MODULATION ERRORS
- SYSTEM ERRORS (PHASE MATCH, STABILITY) COMPLETELY COMPENSATED

ERROR MAGNITUDE ESTIMATES

- Rotor Blade Modulation
  - Limited Data from one Field Test
  - No Other Contractor Data Available
- Azimuth Multipath
  - Analytic Model Formulated
  - Based on EES Related Experience Base
  - No Contractor Data Available

TIMELINE ANALYSIS

- PERFORM INITIAL FREQUENCY SEARCH
- IDENTIFY AND PRIORITIZE THREATS
- DF ON SELECTED THREATS
  - DWELL TO REDUCE ROTOR BLADE ERRORS
  - STEP THROUGH SELECTED THREATS
  - REVISIT TO REDUCE AZ MULTIPATH ERRORS
  - REPORT THREAT LOCATION
- REPEAT FREQUENCY SEARCH

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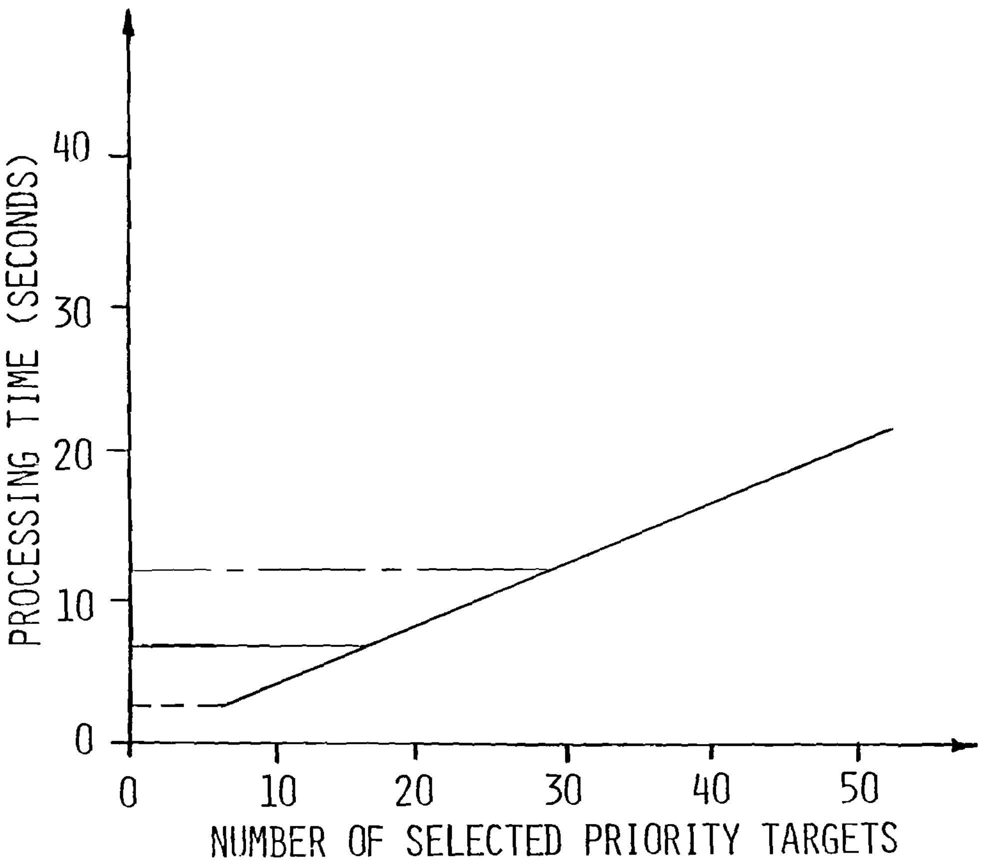
GEORGIA INSTITUTE OF TECHNOLOGY

PROCESSING TIMELINE



PARAMETERS

t_1 = 10 MS (10 PULSES)

Δ = 3.5 GHz

B = 10 MHz

τ_b = 10 MS

$\sigma_b = 1^0$

$\sigma_\theta = 1.6^0$

$\sigma_\theta' = \sigma_b' = 0.5^0$

τ_d:

— — — 1.0s

——— 0.5s

- - - - 0.1s

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY

CONCLUSIONS

- ACCURATE DF CAN BE OBTAINED WITH RFI
- DF TIME FOR SINGLE EMITTER QUITE SHORT
- TIMELINE IS A STRONG FUNCTION OF MULTIPATH DECORRELATION TIME
- MULTIPATH AND ROTOR BLADE MODULATION ELIMINATION ALGORITHMS ARE REQUIRED
- SEVERAL DIFFERENT DEVELOPMENTAL CONFIGURATIONS ARE AVAILABLE
- NEED TO DEVELOP EVALUATION CRITERIA

A-3205

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

August 31, 1982

U.S. Army Missile Command
Advanced Sensors Directorate
Redstone Arsenal, Alabama 35809

Attention: Mr. John Hatcher
DRSMI-RES

Subject: Monthly Progress Letter and Cost Report for July 1982, Contract DAAH01-81-D-A003, Delivery Order No. 00046

Gentlemen:

During this reporting period activities were conducted in the following areas:

1. The analysis to refine the time line equations and alternate processing approaches to reduce the time line has continued.

2. Analysis of requirements for a measurements program to provide phenomenological data and demonstrate system capabilities are underway. The following technical issues are being considered.

   1) Multiple target identification
   2) Angular accuracy/designation accuracy
   3) Bi-static multipath
   4) Triangulation capabilities
   5) Exotic emitters (millimeter, PRF agility, spread spectrum)
   6) Helicopter exposure time (time lines)
   7) Interface with RWR and handoff problems

Cost Report

Project Duration	6 months
Months into Project	4 months
Funds Contracted	$50,000
Funds Expended	$31,450
Funds Remaining	$18,550

Respectfully submitted,

[redacted]

Carlton H. Cash, Project Director

APPROVED: [redacted]

Jerry L. Eaves
Associate Director, RAIL

HELICOPTER MAST MOUNTED SENSOR ANALYSIS REFINEMENT

Final Technical Report

by

Carlton H. Cash, Neal T. Alexander, and George W. Ewell

Prepared for

U.S. Army Missile Command
Army Missile Lab
DRSMI-IYE
Redstone Arsenal, Alabama 35898

Under Contract DAAH01-81-D-A003
Delivery Order No. 0046

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia

October 1982

TABLE OF CONTENTS

SECTION 1
INTRODUCTION

This effort was a follow-on to a previous task order. The previous analysis was undertaken to determine the capabilities of a radio frequency interferometer (RFI) direction-finding sensor mounted on a mast above the blades of a helicopter. Limited experimental tests of selected RFI sensors have been conducted against available targets. In order to assess the performance of the sensors in a realistic battlefield environment, Georgia Tech conducted the previous analysis to extrapolate the test results to include multiple emitters and variation of the sensor parameters.

The general approach was as follows:

- o Collect and analyze contractor system configuration data.
- o Define a generic direction finding (DF) system.
- o Identify primary error sources.
- o Quantify error magnitudes (and decorrelation times).
- o Formulate time line equations.
- o Quantify processing effects on time lines.

The analysis was limited in scope due to the lack of data in several areas. In particular, there is little available information on the magnitude and statistical characteristics of either bistatic multipath or rotor blade modulation. Both of these error sources can have a pronounced effect on system performance.

The family of time lines derived under this previous analysis were highly sensitive to multipath and multipath decorrelation times. Concern was expressed that, if worst case assumptions were correct, the expected exposure times could threaten the ability of the helicopter to perform its mission in the air defense threat and have satisfactory survivability.

The objectives of this follow-on effort were to (1) review the analysis and attempt to obtain additional data with which to refine the results, (2) conduct seminars with contributing contractors pertaining to RF interferometers and discuss results of the Georgia Tech effort, and

(3) provide general support to the government for RF interferometer measurements and interpretation to provide a basis for follow-on RFI tests to address the technical issues.

The general approach was as follows:

- o Briefings were conducted for contributing contractors and government personnel.
- o Additional data were sought, and the time line analysis was reviewed and refined.
- o Potential applications of the RFI to government programs and engineering development aspects were defined.
- o Preliminary approaches to addressing technical issues were promulgated.
- o Additional RFI tests were recommended.

The briefings for contributing contractors were well received; however, additional data or approaches to multipath algorithms were not obtained. The review of the previous Georgia Tech analysis resulted in projected time lines that are much more amenable to helicopter operations and survivability. Outstanding technical issues were addressed and recommendations for their resolutions were made.

SECTION 2

CONTRACTOR/GOVERNMENT BRIEFINGS

One task of the follow-on effort was to revisit the RFI contractors that had been visited on the initial effort (and others as appropriate), brief them on the results of the analysis, and solicit new or additional information regarding multipath and rotor blade modulation. In addition, a briefing was to be given to personnel of the U.S. Army Aviation Center at Ft. Rucker, Alabama, to apprise them of the analysis results.

The briefings that occurred are as indicated in Table 1. In addition to Texas Instruments, Loral, and Litton, all of whom had been visited during the previous effort, a briefing was given to IBM, who had subsequently reentered the RFI arena. The McDonnell-Douglas briefing was given (per their request) to make them aware of the thrust of this program as they are providing the mast mounted sight (MMS) for Advanced Helicopter (Scout) Improvement Program (AHIP).

All of the contractors were in general agreement with the Georgia Institute of Technology/Engineering Experiment Station (GIT/EES) analysis and time line results. A question arose during the Loral discussions as to whether the rotor blade modulation errors were symmetrical and, therefore, whether averaging would actually reduce the error to zero. Loral had concluded that synchronizing the receiver to the rotor blade motion was the best solution, although there were reservations because of the potential for a large angle of exclusion. GIT/EES believes that rotor blade modulation is probably not the dominating factor in the overall system accuracy; in any event, motion averaging will aid in the decorrelation process.

Litton personnel noted that there were numerous instances during the Yuma tests in which there were not noticeable effects due to the rotor blades, presumably because they were not in the direct line-of-sight between the RFI antennas and the emitter. Their feeling was that the rotor blade effects were hardly quantifiable because the test system was not instrumented to measure these effects and there was a significant amount of elevation multipath present which caused large variations in the measured signal level.

TABLE 1. CONTRACTOR AND GOVERNMENT BRIEFINGS

DATE	LOCATION	ATTENDEES	AFFILIATION
09 March 1982	GIT/EES	Ron Brown	Texas Instruments
		Carl Cash	GIT/EES
		Neal Alexander	GIT/EES
		Jim Ussailis	GIT/EES
12 March 1982	GIT/EES	Don Toman	Loral
		George Ewell	GIT/EES
		Neal Alexander	"
		Jim Ussailis	"
11 May 1982	Litton Amecom	Carl Cash	GIT/EES
		Neal Alexander	"
		George Ewell	"
		Jerry Bedingfield*	Litton
12 May 1982	IBM	Carl Cash	GIT/EES
		Neal Alexander	"
		George Ewell	"
		Jim Sawicki*	IBM
22 July 1982	GIT/EES	Bob Alterman	McDonnell-Douglas
		Carl Cash	GIT/EES
		Neal Alexander	"
08 Sept 1982	Ft. Rucker	Carl Cash	GIT/EES
		George Ewell	"
		Neal Alexander	"
		Rich Jones	MICOM
		Bill Dobbs	MICOM
		Don Wagner*	Ft. Rucker

* Principal Technical Representative, others in attendance also.

The typical method used to reduce errors is as follows: ambiguities in direction of arrival (DOA) are removed by phase angle processing, then the largest errors are deleted and the data are averaged, and, finally, a histogram of angular directions is built up from which a most likely direction is estimated. Typical smoothing times are 2 to 5 seconds. The specific algorithms used to perform this processing are based on measured data and field test results. Initial frequency sorting is typically done by means of very high resolution frequency measurements and several scans per second through the range of possible threat frequencies.

In all discussions with the contractors, no additional data on azimuth multipath phenomena were uncovered. There was a general consensus, however, that such data were desirable and that subsequent field tests should be structured to obtain such data in the course of RFI testing, or that experiments should be funded to specifically measure azimuth multipath characteristics.

SECTION 3

TIME LINE ANALYSIS

As discussed in the previous section, it was hoped that contact with various vendors active in the RFI area would provide additional data concerning multipath returns and rotor blade modulation. However, no significant amount of additional useful information was uncovered in either of these areas.

Without additional information concerning the statistical properties of these signals, development of optimized signal processing algorithms was deemed impractical. However, the relatively long exposure times predicted by the earlier Georgia Tech analysis prompted a critical re-evaluation of the time line analysis.

The basic system used in the time line analysis was a scanning superheterodyne receiver. The analysis assumed that the signal-to-noise ratio was sufficiently large and that system errors were sufficiently well compensated so that the only contributions to error were azimuth multipath and rotor blade modulation. The approach used was to first scan the frequency band of interest and to identify the priority threats. These priority threats were next examined for a period of time sufficient to reduce rotor blade-induced errors to a sufficiently small value for each of the threats. The signals were then revisited until the azimuth multipath errors were reduced to acceptable levels.

The original hope was to obtain updated data on the statistical behavior of the return to permit more optimum interleaving of scans, elimination of wild points, and on-line estimation of accuracy. Since such data are not available, the best estimate of errors is still given by the equations from the earlier report.

$$t = t_1 \, \Delta/(2B) + \tau_d(\sigma^2/\sigma_\theta^2)$$

when $n\tau_b\sigma_b^2/\sigma'^2_b < \tau_d$

$$t = t_1 \, \Delta/(2B) + n\tau_b(\sigma_b^2/\sigma_b'^2)(\sigma_\theta^2/\sigma_\theta'^2)$$

when $n\tau_b\sigma_b^2/\sigma_b'^2 > \tau_b$

where:

Δ = RF bandwidth to be searched

B = IF bandwidth

t_1 = dwell time at a single frequency

τ_d = decorrelation time for azimuth multipath

σ_θ = RMS multipath error

σ_θ' = smoothed RMS multipath error

n = number of targets

τ_b = rotor blade modulation decorrelation time

σ_b = standard deviation of blade modulation errors

σ_b' = desired integrated blade error

Since the results are dependent upon the specific values of the variables employed, time line analyses were carried out for a range of decorrelation times. The results of these analyses are given in Figure 1 indicating the current assessment of the sytem timeline. (In some earlier analyses, numerical values of two variables were inadvertently interchanged.)

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY

PROCESSING TIMELINE

PARAMETERS

t_1 = 10 MS (10 PULSES)

Δ = 3.5 GHz

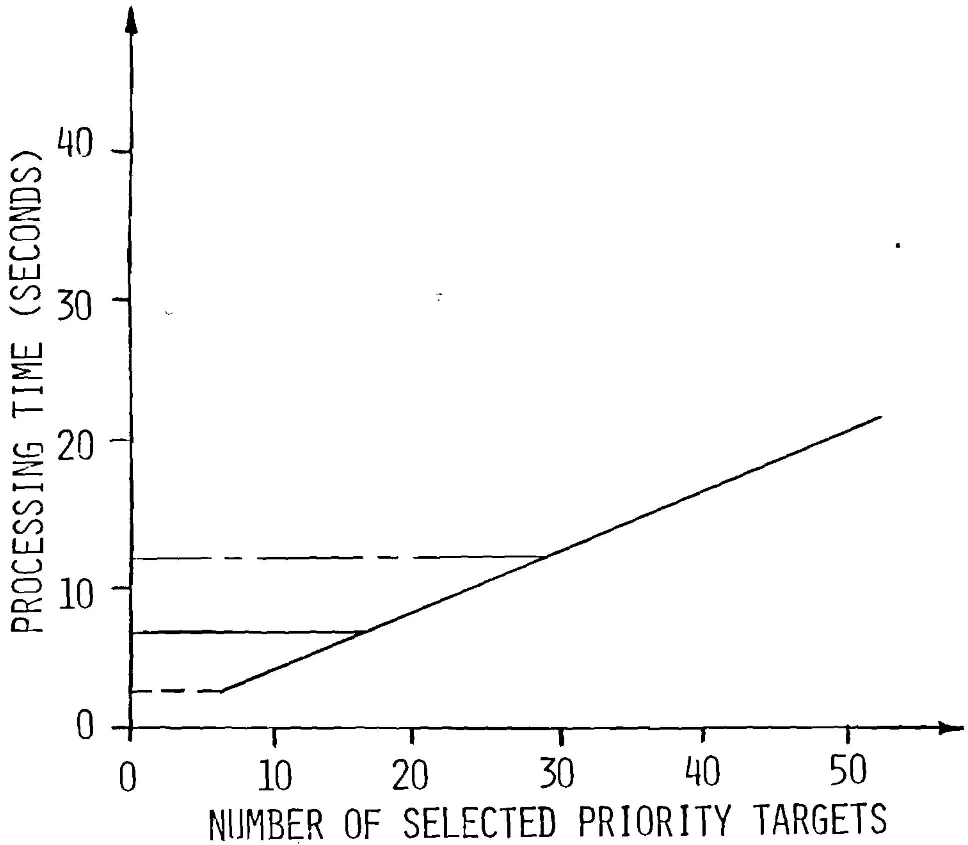
B = 10 mHz

τ_b = 10 MS

$\sigma_b = 1^0$

$\sigma_\theta = 1.6^0$

$\sigma_\theta' = \sigma_b' = 0.5^0$



τ_d:
- — — 1.0s
——— 0.5s
– – – – 0.1s

Figure 1. Processing time line.

SECTION 4

RFI TECHNICAL ISSUES FOR ENGINEERING DEVELOPMENT (ED) INITIATION

The new APR 39-AV1 is presently planned (and under procurement) for all combat helicopters. This is a Radar Warning Receiver (RWR) which uses crystal video and amplitude comparison in frequency bands from 6 GHz to 100 GHz. This capability provides main beam detection and warning to the helicopter when air defense system action is likely and/or imminent. However, it does not provide location of air defense systems to the degree of accuracy necessary for suppression weapons to be utilized effectively. In addition, the sidelobe detection range and accuracy is insufficient to provide fire control and/or cueing to on-board weapon systems. A system capability to provide helicopter self-protection, warning, threat location, and fire control is required.

The RWR must be augmented with an RF interferometer (RFI: 4 GHz to 18 GHz) with growth potential. The RFI will be required to provide accurate DF in a forward sector (90° and 120°). The DF accuracy must be sufficient to put the threat within the field-of-view of current optical fire control and/or missile seekers. In addition, accurate DF on multiple targets will be required, and the DF data must be correlated when the helicopter moves to another location so that threat ranges can be determined by triangulation.

Engineering Development of an RF target location system (RFI) beginning in FY84 is an urgent goal. In order to release a Request for Proposal (RFP) for full Engineering Development (ED), an In Process Review (IPR) is required to provide risk assessment and demonstrate full system capabilities. Generally, an Advanced Development (AD) program is needed to provide the basis for an IPR. However, neither sufficient time nor money is available for an AD program. This AD program requirement can be bypassed provided that sufficient data exist to show potential full system capability at a reasonable risk.

The following technical issues must be addressed:

1. Multiple Target Identification
2. Sensitivity for Sidelobe Performance

3. Angular Accuracy/Designation Accuracy/ Triangulation Capabilities
4. Multipath Effects on Accuracy (Track and Surveillance Radars)
5. Effect of Oxotic Emitters (Millimeter Wave, PRF, Frequency Agility, Med/High PRF Pulse Doppler)
6. Helicopter Exposure Time
7. Handoff to Other Systems

The above technical issues can be addressed by various approaches which will be discussed below.

A. Multiple Target Identification: Techniques for multiple target identification have been well developed and implemented in various ELINT and anti-radiation missile (ARM) programs. These techniques include frequency measurement (FM), direction of arrival (DOA), pulse repetition interval (PRI), pulse width (PW), scanning characteristics, and other measurements of radar pulse parameters. Receiver circuits in the frequency range of 2 GHz to 18 GHz and computer hardware and software programs are available. These techniques are low in cost and risk and may be implemented in an engineering development program to provide the required capability for threat ordering and prioritization.

B. Sensitivity for Sidelobe Performance: The state-of-the-art in superheterodyne receivers (including computer-controlled local oscillators for frequency search, wideband mixers, solid state IF amplifiers, and detectors) is well developed and has been implemented in existing systems. The receiver capabilities required to provide the required sensitivity performance against the threat emitters can be implemented at low risk and reasonable cost using off-the-shelf components. Receiver dynamic range and spurious responses (to intermodulation products (IMP) and harmonics of the incoming signals), are the principal factors which will affect receiver suitability and which will require special design attention during an engineering development program.

C. Angular Accuracy/Designation Accuracy: The multiple-baseline phase interferometer has the excellent attribute of much higher angle accuracy than can be achieved with any amplitude comparison scheme combined with a wide field-of-view. The angle accuracy of the interferometer is determined by the phase error of the widest baseline antenna pair and is thus essentially independent of the antenna beamwidth. Typical interferometer antennas have 90° or greater beamwidths and the degradation of accuracy is small over a ± 45° angle from boresight. The ambiguities of a multiple baseline RFI are resolved by simple truth tables for the multiple baselines and the frequency of the received signals. Interferometers have been implemented with accuracies of 0.1° to 1° RMS over multiple octave bandwidths. The primary inherent errors of phase interferometers are caused by thermal noise, analog to digital converter quantization errors, and bias due to component variations with the receiver. These inherent errors can be made arbitrarily small by proper receiver design and system calibration (both statis and dynamic calibration can be implemented). Equipments have been implemented and tests conducted by several contractors which demonstrated that the required level of inherent angle accuracy may be achieved with these techniques.

The effects of multipath (including that due to helicopter blades) on angle accuracy is a somewhat more complex problem. It is considered essentially a separate technical issue and will be discussed separately.

There are several potential approaches to (and levels of complexity of) the question of target location or designation accuracy. These approaches include the following.

1. Handoff to an electro-optical system or use of a laser range finder in conjunction with the RFI angular measurement.
2. Azimuth/elevation (Az/El) emitter location involving measuring the elevation angle to the emitter and determining the altitude of the aircraft and the target. The target range can then be easily calculated. The latter approach requires a two-dimensional RFI to measure both azimuth and elevation angles to the emitter. Reasonable accuracies can be achieved when the aircraft altitude is relatively large and is significantly compared to emitter range.

However, for nap of the earth (NOE) type operations with a helicopter this is an unsatisfactory approach.

3. Triangulation involving measurement of the angle to an emitter or to several emitters, cataloging and storing data in a computer and moving the helicopter along a baseline, and then again measuring the angle to the same emitters. These two sets of angle data and the baseline data can be used to calculate the emitter position.

4. Time difference of arrival (TDOA), which is a multi-aircraft scheme, wherein the time and angle of arrival of a pulse are simultaneously measured by two or more non-colocated receivers and forwarded to a central processing location for calculating emitter location. This technique requires highly complex systems with synchronized time reference, wide band data links, and a high performance central processor; however, TDOA systems can be designed with excellent accuracy.

Current attack helicopter weapon systems utilize optical and/or electro-optical fire control and missile guidance. Therefore, accurate RFI location of the emitters in azimuth angle only is a very valuable adjunct which can quickly place threat air defense radars within the field-of-view of the optical systems. However, for the Scout helicopter to hand off the location of targets to attack forces, the emitter range is a very valuable parameter. Triangulation can be implemented fairly simply for a helicopter with an accurate navigation system, and is compatible with NOE operations; however, little if any data exist to validate this technique. Therefore, a test program needs to be conducted to determine the efficacy of this approach and to assess the technical risk involved in proceeding to an ED program.

D. Multipath Effects on Accuracy (Track and Surveillance Radars): The effects of multipath on angle accuracy of RFI systems have been analyzed and the effects on the time line estimated for helicopter mast mounted sensors. However, insufficient bistatic multipath data exist to determine the decorrelation time and the probability of occurrence of serious multipath for tracking and surveillance radar emitters. Therefore, quite large variations in the time line and/or accuracy may occur. Additional tests are needed to investigate multipath decorrelation times and to explore the potential multipath elimination algorithms and also to assess the risks associated with multipath effects on system performance.

E. Exotic Emitters (Millimeter, PRF, and Frequency Agility): The current radars of the air defense threat to Army helicopters operate in frequency bands between 2 GHz and 18 GHz; however, it is probably sufficient to implement RFI coverage over several somewhat smaller frequency bands. The millimeter spectrum will add a new dimension to the complexity of the hardware required and the state-of-the-art has not been developed and demonstrated for this frequency coverage. Near-term engineering development to include millimeter wave frequency bands would significantly increase the cost, complexity, and risk of the program. Growth potential to implement millimeter coverage should be considered. However, in the interim the RWR millimeter wave capabilities should provide protection from threats in the millimeter wave bands.

PRF agile and frequency agile waveforms could become future emitters of interest to the RFI. Techniques and approaches for countering these waveforms have been developed. However, the requirement for including these waveform capabilities should consider the implications on cost and complexity against the potential increase in utility.

F. Helicopter Exposure Time: The helicopter exposure time to locate emitters is directly related to the time lines discussed in Section 3 of this report. These time lines are predicated upon algorithms for multipath and rotor blade modulation reduction. Since multipath decorrelation time is not well defined, additional tests need to be conducted to assess the accuracy of these time lines so that proper algorithms can be implemented and the time lines can be accurately predicted.

G. Handoff Problems: The handoff of RFI data on board an attack helicopter can be provided to the operator through an interface to existing optical data displays. Use can be made of existing communication channels for the Scout to handoff to attack forces. However, the potential advantages for improved data links should be analyzed.

SECTION 5
RF INTERFEROMETER TEST PROGRAM

MICOM's mission includes missile fire control, which in the context of this program would be when the RFI is used directly to provide information for missile attack of and guidance to the threat. ERADCOM's mission includes surveillance and target location for warning and/or handoff to weapon systems (e.g., artillery) as is the primary role of the Scout helicopter.

A joint ERADCOM/MICOM program to spearhead the development of an RFI could provide the basis for an IPR and release to ED in FY84. Development of a strategy for gaining support from TECOM, AVRADCOM, and user to support IPR based upon less than an AD program is needed.

RF interferometer hardware has been developed by several contractors and tests conducted by MICOM at Redstone Arsenal and at Yuma Proving Ground. In addition, studies and simulations have been sponsored to determine the efficacy of the helicopter mast mounted RFI. Georgia Tech has performed analyses to extrapolate these test results to a multi-emitter environment and to determine the effects of the battlefield scenario on accuracy and time lines.

An additional RF interferometer test program is needed to support the IPR for release to ED. There is not sufficient time and money to complete a procurement package to hardware contractors; therefore, they would be offered an "opportunity" to demonstrate their capabilities, to gather data to demonstrate a system capability, and to address the technical issues discussed above. Such tests would include tower and helicopter mast mounted tests. Vendors that do not have hardware currently suitable for helicopter integration should be offered the opportunity to perform tower tests only.

In order to support the FY84 ED program, the tests must begin in April 1983. Therefore, the timing is critical and the following GIT/EES support is recommended:

1. Develop Test Plan
2. Design and/or Support Helicopter and Instrumentation Interface
3. Provide Data Gathering Support

4. Provide Additional Threat Simulators
5. Reduce and Analyze Data
6. Generate a Systems Requirements Document.

The development of a test plan is a critical first step in this program and it, therefore, should be accomplished prior to steps 2 through 6. The objective of such a task would be to design a comprehensive test plan for the evaluation of the performance of contractor-provided RF direction finding sensors mounted on the mast of a helicopter above the rotor blades. The tests could be conducted at the U.S. Army Missile Command at Redstone Arsenal, Alabama, and would provide a realistic battlefield environment, including several threat radars, simulators, and conditions conducive to azimuth and elevation multipath interference. The test plan should address, at a minimum, the threat radar environment, the data acquisition system and procedure, the interface between the contractor sensors and the data acquisition system, the facility support requirements, the agency responsibility assignments, and the data analysis procedure. A three month period of performance would be required to perform such a task.